

Bio-Compatibility of Alumina (Al_2O_3) Ceramic Thin Films

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ABSTRACT

Bio ceramics are ceramic materials that are bio compatible. The class of ceramics used for repair and replacement of diseased and damaged parts of musculoskeletal systems are termed bio- ceramics. Bio-ceramics range bio-compatibility from the ceramic oxides which are inert in the body, to the extreme of resorbable materials which are replaced by the materials which they are used to repair. Bio-inert high strength materials (Zirconia, Alumina) do not release any toxic constituents, they do not show positive interaction with living tissue. The different concentration of Alumina thin films were examined by spray- pyrolysis technique. The deposited films were subjected to X-ray diffraction (XRD), Scanning Electron Microscopy (SEM). The cytotoxicity and mechanical behaviour of bio-inert Alumina ceramic thin films shows that bio-compatibility of material.

Keywords: Alumina, Bio ceramics, spray pyrolysis, mechanical properties, Bio-inert.

1. INTRODUCTION

The challenge for the materials scientists is to develop new ceramics that produce the most appropriate response that the clinical situation demands. It has been accepted that no foreign material placed within a living body is completely

compatible. The only substances that conform completely are those manufactured by the body itself. No synthetic material can be considered as being inert as all materials will produce some sort of a response from living tissue. These materials will be recognized as foreign and may initiate any of a range of tissue responses.

In general, bio ceramics can be classified according to their tissue response as being bio inert, bioactive, or resorbable ceramics¹. Bio ceramics become an accepted group of material for medical applications, mainly for implants in orthopaedics, maxillofacial surgery and for dental implants. Dozens of ceramic compositions have been tested. However few have achieved human clinical application².

In the present work, we first utilized the preparation of Al_2O_3 bio ceramics using thin film techniques and their biocompatibility, mechanical properties and applications are also discussed.

2. EXPERIMENTAL DETAILS

2.1 Preparation of Alumina (Al_2O_3) Ceramics

Thin films of Alumina (Al_2O_3) Ceramics were obtained using the spray pyrolysis deposition technique (SPD) from an aqueous solution. Alumina (active basic compound material with PH 6.5-7.5), and deionized water were used as precursor solution. Using a hot plate the substrates were heated at the deposition temperature. The deposition parameters such as the spraying distance from the nozzle to the substrate and the carrier gas pressure were set at previously optimized values³. Thus, the spraying distance was 20 cm and was kept constant for all depositions. Temperature was invariant at 450°C. The mechanical behaviour of the sample was studied for metal rod shape materials. The rod was prepared by injecting alumina solution into metal cylindrical / rectangular rod. The metal rod was heated at 700°C, and

then the rod was cooled to room temperature gradually.

2.2 Material Characteristics

An alumina ceramic has characteristics of high hardness and high abrasion resistance. The reasons for the excellent wear and friction behaviour of Al_2O_3 are associated with the surface energy and surface smoothness of this ceramic. There is only one thermodynamically stable phase, i.e. Al_2O_3 that has a hexagonal structure with aluminium ions at the octahedral interstitial sites. The characteristic features of Abrasion resistance, strength and chemical inertness of alumina have made it to be recognized as a ceramic for dental and bone implants. Currently alumina ceramics are widely used for bearing surfaces THR⁴. Alumina bio ceramics are used as replacement parts in hip and knee operations. The inertness of the ceramic, its high wear resistance and its excellent biocompatibility make it the ceramic of choice. The high load-bearing property of alumina also makes it an ideal ceramic for dental implants. We examined the alumina ceramic rods with 376.48 to 378.94 young's modulus [GPa] was obtained and it also very close to the reported values⁵.

3. RESULTS AND DISCUSSION

3.1 XRD analysis

The structural analysis of alumina ceramic thin films was carried out by using X-ray diffractometer. The material was scanned in the range 10-90°. Figure shows the plot of intensity (in arbitrary unit) against 2θ, where θ is the angle of incidence

of X-ray beam. The XRD analysis shows that the thin films are trigonal (hexagonal axes) crystal system with polycrystalline nature. It is seen from Figure 1, the (012) peak appears with maximum intensity at 25.59° . The other peaks at 35.02° , 37.71° , 43.37° , 52.48° , 57.40° , 66.54° , 68.16° , and 77.39° can be associated with (104), (110), (113), (024), (116), (214), (300) and (119) peaks of Al_2O_3 , with the lattice constants of $a=4.7469\text{\AA}$ and $c=12.9835\text{\AA}$, which is almost in agreement with the Standard data from JCPDS card No.96 – 100 - 0060. The strong preferred c-axis orientation is evident from the figure 1. There is no any other peaks are identical, because of ceramic thin

films were synthesized at lower temperatures. But the average grain size was increased further if we increase the temperature of synthesis process get a favorable results.

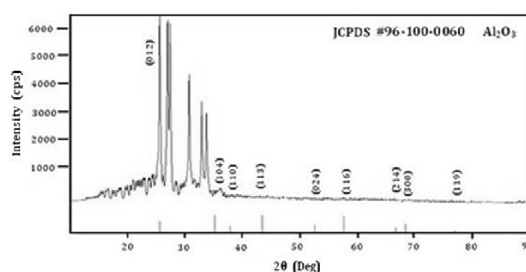


Fig.1 XRD pattern spectrum of the semi-crystalline Alumina ceramic thin films

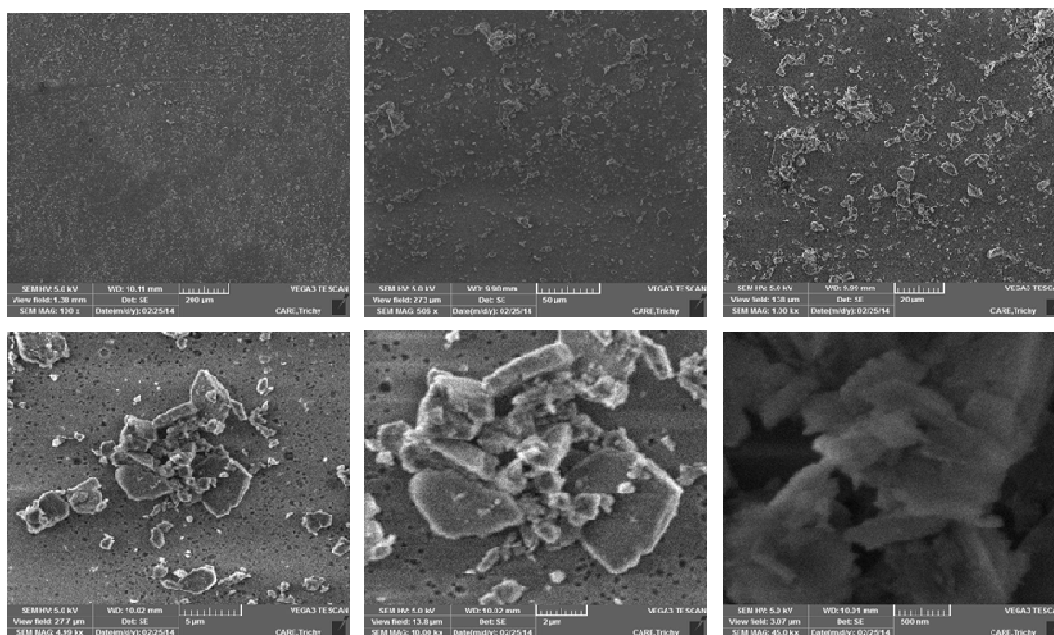


Figure 2: The SEM image of the ceramic Alumina thin film (a) 200 μm (b) 50 μm (c) 20 μm (d) 5 μm (e) 2 μm (f) 500 nm

3.2 Morphological analysis

One of the important applications of

the SEM is to obtain the knowledge of the material composition. Scanning electron microscope image of Al_2O_3 were shown in

fig 2. (a-f). SEM picture gives information about ceramic film on glass plate. Fig 2.1(a) enlarged at 200 μm large. The density of the material more at the left, but at the right of the picture gives comparatively less density. For the focusing of close to 50 μm and 20 μm SEM image fig 3.1 (b&c) representing small clusters of grains of size about 115 nm-200nm. Fig 3.1 (d-f) shows the Al_2O_3 film formation with cluster of grains forming the big particle of size of 500 nm-2000nm. Surface morphology of the Al_2O_3 ceramic makes it useful in orthopedic applications.

4. CONCLUSIONS

An excellent biocompatibility of Alumina (Al_2O_3) ceramic thin films were prepared by spray pyrolysis deposition technique. The X-ray analysis bio-inert alumina ceramic was polycrystalline in nature, semi crystalline structure. Surface Morphology of the Al_2O_3 gives average grain size. SEM image representing small clusters of grains of size about 115 nm-200 nm. The Al_2O_3 films with cluster of grains are combined together and forming the big particles of size about 500 nm-2000 nm. Surface morphology of the Al_2O_3 ceramic makes it useful in orthopedic applications. The analyses of the results from the

cantilever method Al_2O_3 ceramic have high mechanical strength. The measured value of Young' Modulus of alumina ceramic was (376.48 to 378.94 GPa) matched with the standard value. The characteristic features of Abrasion resistance, strength and chemical inertness of alumina have made it to be recognized as a ceramic for dental and bone implants. The high load-bearing property of alumina also makes it an ideal ceramic for dental implants.

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